PB82-218579

Substrategy for Construction Site Noise Abatement

(U.S.) Environmental Protection Agency
Washington, DC

Aug 81

U.S. Department of Commerce
National Technical Information Service
NTIS

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA/550/9-82-151	2. PB82-218579
4. TITLE AND SUBTITLE Substrategy for Construction Noise Abatement	5. REPORT DATE August 1981 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Dr. Paul U. Pawlik	8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Environmental Protection Agency Office of Noise Abatement and Control Washington, D.C. 20460	10. PROGRAM ELEMENT NO. 11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS U.S. Environmental Protection Agency Office of Noise Abatement and Control Washington, D.C. 20460	13. TYPE OF REPORT AND PERIOD COVERED 14. SPONSORING AGENCY CODE EPA ONA
15. SUPPLEMENTARY NOTES	

16. ABSTRACT

This study outlines a national strategy to address construction site-noise. After explaining the peculiar nature of construction-site noise and estimating the population exposed to high noise levels, the author presents viable methods to control such noise. It was found that in non-regulatory solutions are the best solution, after analyzing controls using criteria like: the effectiveness in reducing noise exposure, the speed with which effectiveness is obtained, the relative overall cost to contractors, and the proper place of primary responsibility.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Noise Exposure (Construction Sites) Construction Equipment Noise Exposure Noise Controls (Construction Site Noise) Regulatory Options Construction Noise Regulatory Alternatives Construction Noise Costs/Benefits Construction Noise Control		

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES 41
	20. SECURITY CLASS *(This page)*	22. PRICE

EPA Form 2220-1 (9-73)

PB82-218579

EPA/550/9-82-151

SUBSTRATEGY FOR CONSTRUCTION SITE NOISE ABATEMENT

AUGUST 1981

U. S. ENVIRONMENTAL PROTECTION AGENCY
Office of Noise Abatement and Control
Washington, D. C. 20460

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U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA 22161

A STRATEGY FOR STATE AND LOCAL GOVERNMENTS FOR THE CONTROL AND ABATEMENT OF NOISE FROM CONSTRUCTION OPERATIONS

FINAL REPORT

AUGUST 1981

Dr. Paul U. Pawlik

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EXECUTIVE SUMMARY

Although the Federal Government has decided to reduce EPA's future participation in the control and abatement of community noise, including noise from construction sites, efforts to reduce noise exposure should not be abandoned, because much can be done at the local level. This report presents the opportunities, means, estimated costs, and potential benefits that are available to the States and, particularly, to the communities that wish to reduce the noise from construction activities.

Specifically, a thorough examination of construction site noise indicates that:

- Quieter construction equipment, designed using available technology, would not, by itself, solve the construction site noise problem.

- Since construction noise is site-specific, a primary thrust of construction noise control must rest on in-use controls which can be expressly tailored to a specific situation.

- In-use controls are best implemented at the local level where all factors can be considered, where suitable ordinances can be passed and enforced, and where appropriate penalties can be levied.

- In-use controls are effective and can be instituted voluntarily by construc tion contractors and/or mandated by local ordinances. These controls include

  - operation of construction equipment with all noise reducing components (such as mufflers) in place and in good repair,

  - location of equipment on the site and operation in a manner that reduce noise levels at the receivers,

  - use of alternate construction methods,

- scheduling the operation of noisy equipment concurrently to reduce total noise duration or scheduling operations at times that match high ambient noise levels from other sources,

- curfews on construction activity, and

- upper limits for noise levels at the property line.

- Other methods which can be imposed locally to control construction noise include

  - use of shields, enclosures, and noise barriers or berms,

  - adoption of Buy-Quiet programs, and

  - local demonstrations of leadership in noise reduction in municipal construction and maintenance.

- Local ordinances are effective in controlling construction site noise only if there is an effective enforcement mechanism.

- Costs of typical local construction noise reduction programs (including the enforcement portions) are minimal. This is because it is likely that construction noise programs will be adopted only by communities that have programs for controlling noise from other sources. Consequently, the construction portion has only a relatively small marginal cost.

There is no reason for States and localities to wait. They should act now to enforce existing anti-noise provisions and, in the absence of existing provisions, they should study model noise codes and act to adopt those provisions which are best suited to serve their needs.

I. INTRODUCTION

Noise from construction sites is comprised of approximately 22 different categories of contributing noise sources. To further complicate the problem, construction site noise is dependent upon an equipment mix which, in turn, is generally dictated by the type and the stage (i.e., clearing, excavation, foundation, erection, and finishing) of the construction activity. Although EPA anticipates that the number and the predominant type of construction activities will vary from year to year because of the construction industry's sensitivity to national economic conditions, EPA does not anticipate a significant upward trend in construction nor significant shifts in population density near construction sites. However, a continuing transition is occuring from small size equipment to larger, more powerful units in an effort to increase productivity and decrease overall construction costs. This trend brings with it higher noise levels and the attendant increases in the severity and extensiveness of construction site noise impacts.

The Federal Government has decided to reduce EPA's future role in the control and abatement of community noise. The subject of this report is consistent with that decision and represents timely assistance in the transfer to State and local governments of EPA's nationwide responsibility for reduction of the noise from construction sites.

Much of the information in this report has been collected since the Federal decision was made. Representatives of State and local governments whose opinions are described here were aware that their responsibilities were going to be greater than they had been, so their views represent, in part, their plans for their own activities. Manufacturers knew that it is unlikely that the noise levels of their equipment and replacement parts would be subject to Federal limitations on noise emissions except, possibly, at the operator's position as protection against occupational injury. Therefore, their comments were based on their plans to compete in a market with less Federal intervention than previously possible.

This report presents the opportunities, means, costs, and estimates of the results that are available to States and, particularly, to communities that wish to reduce the noise from construction activity.

Construction noise is a site-specific problem. There is no blanket prescription for controlling construction noise and the exposure to the noise. Similar types of construction activity can have different exposure impacts, depending on the location of the construction and the population surrounding the site.

The uniqueness of each construction site calls for a combination of control techniques centered around those measures which can be directed specifically to the type of site and the resultant exposure. For the most part, this is best done at the local level, where all factors can be considered, ordinances can be enforced, and if necessary, penalities can be levied. The primary thrust of construction noise control, therefore, must revolve around in-use controls.

In-use controls include hours of operation, operation of equipment with noise control equipment, location of the equipment on the site, use of alternate equipment, rerouting vehicles, property-line standards, and operator concern. These controls can be effective immediately after a local ordinance is passed.

Adverse effects from noise are caused not only by the level of noise, but also by the time of day or night in which the noise is made. For example, noisy operations in a commercial area are best done after regular working hours, when most workers are at home. Conversely, noisy operations in a residential area are best performed during the day, when most people are not sleeping and many are not at home. Although the overall level of noise from the site may not be mitigated, exposure to the noise can be greatly reduced.

Large reductions in noise levels (and exposure) can be achieved by the operation of construction equipment with its proper noise control equipment in place and in good repair. For example, correcting a defective muffler can reduce the noise by 10 dB. Operator concern can greatly affect the way equipment is used and maintained. Such concern can be developed through information dissemination and training. Although no data are available, a possible side benefit is fuel conservation which may occur through proper use and maintenance of equipment. For example, chances are that a truck in good repair with a proper exhaust system and a temperature actuated fan will be more efficient than a truck with improper back pressure resulting from a defective exhaust system and a direct-drive fan.

A noise-sensitive community has many tools at hand to control construction noise. Exhibit I-1 shows the features of most of these controls. The in-use controls can be effective in reducing noise exposure, can be implemented quickly, and can be expressly tailored to each communities needs. The following sections explore the various ways that construction site noise can be controlled by the community.

Before this report was developed, a thorough search of the literature on this subject was examined. In addition, the following topics were studied in depth:

the nature of construction
the geography of construction sites
the phases of construction activity
different construction techniques and equipment
construction equipment noise emissions
equipment used on construction sites
locations and activities of the population affected by construction noise
estimates of the relative exposure of populations to construction noise
in-use controls
path controls
product and noise control information
design changes and retrofitting
financial incentives

Also in preparation of this report, many valuable contacts were made to develop the perspective of all interested parties on the issue of construction site noise abatement. The contributions of these organizations are gratefully acknowledged. A complete list of the organizations that contributed valuable information in this way to the report is provided in the Appendix.

	Effectiveness in reducing noise exposure	Speed with which effectiveness is obtained	Relative overall cost to construction contractor	Place of responsibility primary
A. In-Use Controls				
hours of operation	medium	very fast	medium	local
use of noise control equipment	high	fast	medium	State & local
maintenance	medium	fast	medium	local
equipment location at the site	medium	fast	low	local
use of alternate equipment	medium	fast	medium	local
rerouting vehicles	medium	very fast	medium	local
operator concern	high	fast	low	private sector
B. Path Control				
barriers and berms	low	fast	medium	State & local
shielding	low	fast	medium	State & local
enclosures	medium	fast	medium	State & local
land use controls	low	fast	medium	local
C. Product Information	medium	slow	medium	private sector
D. Design Changes and Retrofitting				
new product regulations	medium	slow	high	Federal, State & local
accessory regulations	medium	slow	high	Federal State & local
retrofit modifications	medium	medium	high	Federal State & local
innovation	medium	slow	high	private sector
E. Financial Incentives				
penalties for noisy operation	medium	medium	medium	local
higher prices for quiet operations	medium	medium	none	State & local
greater documentation requirements	medium	medium	low	local

EXHIBIT I-1: FEATURES OF NOISE CONTROL OPTIONS
(ESTIMATES BASED ON LIMITED DATA)

II. CURRENT PREVALENCE AND SEVERITY OF THE CONSTRUCTION NOISE PROBLEM

A. RESULTS OF DISCUSSIONS WITH STATE AND LOCAL NOISE CONTROL PROGRAM OFFICIALS

Discussions were held with officials, mostly members of the National Association of Noise Control Officials, in about 50 State and local governments that have active, working noise control programs. These discussions covered specific provisions of their laws and enforcement practices, their successes and their suggestions for other communities in the future. The conclusions are as follows:

1. Construction noise is not a severe problem, but it is one of many sources of complaints to which they respond.

2. Most of the complaints are about early starts on sites in residential areas; sometimes about construction noise on Sunday; frequently these are violations of curfews. The remedy is a visit to the construction site to remind the manager about the curfew and to give a warning that he must obey.

3. Some complaints are about excessive noise during hours when construction is permitted. When there is a receiving property noise level limit, the official investigates and makes a measurement; if there is a violation, the official begins negotiation with the site manager.

4. An effective enforcement technique is the preconstruction conference at which the contractors are reminded of the provisions of the local laws about noise (laws about dust, overloading trucks, traffic regulations, parking restrictions, and similar topics may be discussed at the same meeting) and warned that these laws will be enforced if complaints are received. Some contractors ask about the noise restrictions before they prepare their bids; this happens only when the contractors have had some experience with the local officials and know that restrictions are enforced. At some preconstruction conferences the officials request that the contractors use alternative equipment or build enclosures.

5. Contractors almost uniformly are cooperative. Reasonable solutions are found to reasonable complaints. Occasionally a site is shut down by the officials in a place where the noise program is well established and supported by the government and the citizens. The U.S. Army Corps of Engineers however, has been uncooperative in several cases. In one case they became cooperative after having been told about Executive Order 12088 dated October 13, 1976 which requires cooperation with local officials and conformance (except in rare cases) with local standards and acts.

6. None of the officials had any contact with equipment operators or their unions. Even when the local official was a part of the health department, there was no connection between the community noise control program and the occupational noise program.

7. Only a few local ordinances exempted municipal equipment from their provisions regarding noise limits; none of the local officials favored such provisions. They all thought the local government should set an example, and several of them cited the Buy Quiet program as part of the local effort at noise reduction.

The results of these discussions can be compared with surveys made shortly before EPA's phasedown of its noise control and abatement activities.

For example, EPA made a survey[1] of 580 State and local governments and found that between one-quarter and one-third of them reported that construction noise was a problem in their jurisdictions. It was the seventh or eighth most frequently cited problem. (The most frequently cited sources were transportation vehicles.) Very few State respondents believed that the State was making progress in reducing the significance of construction noise as a problem; of the local officials only 40 percent believed that they were making significant progress in reducing construction noise.

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[1] *"State and Local Noise Control Activities, 1977-1979," U.S. Environmental Protection Agency, 1979.*

The National League of Cities surveyed nearly 700 large and small cities in 1980. About three-quarters of the respondents replied that construction noise made some contribution to the noise level in the city, but in the large cities (above 50,000 population) about 17 percent thought that the contribution was substantial. In small cities only 7 percent thought the contribution was substantial. In the large cities, 26 percent of the respondents thought significant progress had been made in reducing noise from construction; in the small cities the corresponding percentage was 9. Officials of both sizes of cities felt that the Federal assistance they valued highly were loans of noise measurement equipment, public information materials, training, and technical assistance.

As a final example, in 1979 and 1980 the National Association of Noise Control Officials and the National League of Cities recommended that EPA place a low priority on its activities and concerns for construction noise reduction.

B. RESULTS OF DISCUSSIONS WITH CITIZENS' GROUPS

Discussions with representatives of Citizens Against Noise, the National Association of Neighborhoods, and one other citizens' group indicated that construction noise sometimes initiates concern for noise control in a community, but more often it is transportation noise or animal noise. Construction noise is not a high priority concern of either noise groups or neighborhood groups. Sometimes noise is a part of a citizen's complaint about a construction activity, e.g., a highway or a building of which the citizens disapprove for long term reasons. In one case in Japan pile driving was halted for three months because citizens organized an antinoise group and demanded compensation.[1]

In 1973 Newman[2] concluded from a survey of citizens near construction sites in Chicago that:

> "1. Noise, dust and dirt, traffic congestion, parking, poor housekeeping, and inconsiderate behavior constitute the most annoying aspects of construction activity.

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[1] *Kyoji Mugikura and Minotu Harada, "Study on Pile Driving..." Internoise 77, p. B-509.*

[2] *J. Steven Newman, "Subjective Community Reactions to Construction Noise," M.S. in C.E. thesis, Northwestern University, Evanston, Illinois, August 1973, pp. 98, 100.*

"2. In rank order, noises considered most unacceptable: impact noises; air hammers, chippers and pile drivers; diesel-driven equipment; trucks; cranes and cement mixers; hi-frequency audible tone devices; electric saws.

"3. The activity most disrupted by noise is sleep.

"4. The majority of the community (75 percent) felt that no recourse was available in dealing with noise annoyance. Few of the remaining 25 percent mentioned calling an official, and virtually no one out of the nearly 150 interviews mentioned the Chicago Department of Environmental Control (D.E.C.). [It can be concluded] that very few citizens seem to be aware of D.E.C.'s existence.

"5. The vast majority (87.5 percent) of the community considers construction noise predictable. It is most likely that a period of adaptation exists. That is, between the hours of 7:00 a.m. to 9:00 a.m., people having just awakened are more apt to be startled and annoyed by construction noise.

"6. The influence of "other factors" on annoyance can be [estimated] by considering the percent of individuals with complaints other than noise.

* * * * * * * * * * *

"17. Downtown residents and workers are roughly 10 NPL [Noise Pressure Level] (db) less sensitive to noise annoyance than outlying residents.

* * * * * * * * * * *

"19. ...Roughly 42 percent of the perimeter residents to construction sites are annoyed by the activity."

Large and Ludlow[1] studied the relationship between noise level at a road construction site in England and attitudes concerning annoyance. They also considered the relationship between other factors and annoyance. Several different statistical and energy equivalent measures of construction noise levels correlated well with annoyance and with extreme annoyance. The various measures were equally good indicators, and all were better when applied to construction noise than to highway noise. The level of annoyance rose more rapidly with increased levels of construction noise than it did for highway noise. Other factors that correlated with the annoyance caused by construction noise included attitudes toward preventability of construction noise and opinions on living conditions. In general, disapproval of construction noise was more pronounced than of noise in general.

C. RESULTS OF DISCUSSIONS WITH LABOR UNIONS THAT REPRESENT CONSTRUCTION WORKERS

Union representatives reported that noise is one of the health and safety hazards against which the members should be protected. They further stated that the contractor is chiefly responsible for the workers' safety and protection from health hazards. In several unions noise is a relatively new concern and programs are being developed to make their locals aware of the health hazard of long term exposure to occupational noise by construction workers. The mobility, lack of permanence of employment, and seasonal nature of the employment make noise exposure less predictable than it is in factories. In general only the noise exposure of the operator of a particular piece of equipment is a current concern. Some locals have developed their own programs in response to the noise exposure problem, but, generally, these efforts have been few and not well organized, particularly at the national level.

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[1] *Large, J.B. and J.E. Ludlow, "Community Reaction to Noise from a Construction Site," Noise Control Engineering, March-April 1976, pp. 59-65.*

III. AVAILABILITY AND APPLICABILITY OF SOLUTIONS

A. RESULTS OF DISCUSSIONS WITH MANUFACTURERS

Manufacturers contacted almost uniformly stated that noise-suppressed product lines using state-of-the-art technology were available, or soon would be available to customers.[1] In several cases, entire product lines were being redesigned and re-engineered and would include noise control features which were intended to control operator noise exposure and/or environmental ("bystander") noise. They pointed out that these efforts are not mutually exclusive. A few offered retrofit noise kits or would do so if their customers demanded it, but considered this a more costly approach compared to engineering quiet into the product. Similar views were expressed to ORI[2] in their survey of equipment manufacturers. Manufacturers stated that since a "large effort creates loud noise," major noise reductions were doubtful.

All manufacturers contacted indicated that their equipment noise control program had been started in response to: (1) OSHA operator noise exposure standards and/or (2) commercial market pressures for quieted equipment in their European markets. Nearly all stated that competitiveness on the European market had been the most significant factor. Competitiveness on the U. S. market was far less significant except in the case of farm machinery, where quiet is demanded. Instead, regulatory requirements were more important in the United States than direct customer demand. That may change in the future as the "Buy Quiet" word spreads, in fact, some States have already made quiet equipment features part of their purchasing specifications.

Noise supressed features included quieted cabs, improved engine enclosures, vibration isolation mounting, improved mufflers, larger fan diameters, cooling system redesigns, use of hydraulically generated force instead of mechanical force wherever possible, and

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[1] *In the literature on construction equipment noise during the past decade there are repeated statements that manufacturers are developing, designing, and manufacturing quieter products. Apparently, the statements are true, but construction equipment lasts a long time and really major changes in the design of successful products are made infrequently. It will be at least 1990 before measurements of noise at typical construction sites will be significantly lower as a result of newer, quieter equipment.*

[2] *C. W. Patten, et al, "Construction Noise Control Technology Initiatives," ORI, Inc. Technical Report 1789, September 1980.*

the addition of absorptive and barrier materials. However, very little cost information could be obtained. All stressed that after-sale customer modifications and/or abuse was a significant problem and that there were tradeoffs to be made, such as quiet vs. productivity, fire hazards, and increased engine and cab cooling problems.

B. RESULTS OF DISCUSSIONS WITH CONTRACTORS

Contractors see themselves as operating in an increasingly difficult and highly competitive business, with evermore stringent and complex rules. Noise to them is not one of the big problems, usually, but there is some awareness of noise control. One representative put the matter clearly for his company as follows:

> "Most of our projects are earthmoving operations outside the metropolitan areas. We have not been subject to major complaints from municipalities and residents regarding equipment noise. We have begun a program of identification of the equipment noise levels from the spectator's viewpoint and hope to be able to predict the expected noise level of a typical fleet as a result of these investigations. When faced with noise restrictions, we expect to use our knowledge of the equipment noise level to select machines which will fall within the restrictions, and, if not, to schedule the operation of the machines either during the operating period or on a shift basis to fall within the community restrictions for noise control. During the period when machines in our current fleet, or manufacturers of major construction equipment have not been able to meet the community standards, additional cost will be built into the operation. These higher costs will be due to the use of smaller machines which will probably be less productive, more costly to own, or they will require the modification of the operation or existing machine to meet the standards. Whenever possible, the selection of the machine hauling route, loading cycle, and grades on which machines operate can be arranged to be least offensive to the community. Noise absorption screens, and wall treatments will probably be very difficult for large earthmoving operations. Small construction sites and individual pieces of equipment could be treated.
>
> "...noise control on current off-the-road vehicles is too expensive for the quality of results we have been able to achieve. Comfort, visibility, and appearance have not been given proper consideration in these designs."[1]

[1] *C. E. Sanders, "A Contractor's Approach to Noise Control of Off-Road Vehicles," Noise-Con 73 Proceedings, 1973.*

Results of contractor contacts in the Washington, D.C., and Baltimore, Md., area confirm that contractors generally have few problems with the construction workers or the unions on the subject of noise, and their problems with the public are likely to be temporary except in the cases of very long term construction such as that for subway construction. Contractors in the Baltimore-Washington area indicated that complaints are received from nearby residents, community groups, and occasionally building inspectors concerning impact equipment noise, about noisy air compressors along sidewalks, and about early starts and Sunday demolitions. They reply to these as reasonably as they can, but their chief concern is to get in and get out quickly with a satisfactory job behind them. Contractors sometimes will try to get and use quieter equipment, but, except in sensitive situations, they usually will rent their equipment (many do not own much equipment and rent it from suppliers) on the basis of price and availability rather than on special features such as quiet. Often they will try to locate equipment on the site so that it is as far away from residential areas as possible, and will employ sound barriers or noise shields in some cases. They welcome preconstruction meetings with local officials, but noise is seldom a major topic; usually it is not mentioned. Notification that a construction site can be shut down for reasons of excessive noise is viewed as sufficient inducement to comply with local noise regulations.

Discussions with contractors reported by ORI in their report[1] also showed that contractors find that mufflers and other noise suppression equipment, if not designed well, tend not to stand up well in the field or make the equipment hard to maintain or service. They also expressed the view that, considering the long operational life of construction equipment, it was costly and impractical to render the older equipment obsolete on excessive noise reasons alone.

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[1] *C. W. Patten et al, op. cit.*

C. QUIETER EQUIPMENT

A 1980 "Quiet Construction Equipment" report[1] showed the most current information from about 150 manufacturers of construction equipment, divided into earthmoving equipment, stationary materials handling equipment, impact equipment, and miscellaneous equipment. Within each class of equipment there are some units that are significantly quieter than others. The literature is full of articles on quieter equipment and techniques for equipment quieting.[2] All emphasize the potential significant deterioration in the field if the equipment is not maintained properly.

Information on the costs of quieting equipment or providing quiet equipment is not widespread, but some information is available. For example, Informatics, Inc. presents some data on the cost of hand-held, noise-suppressed pavement breakers and rock drills and on the costs of muffling pile drivers.[3] Pavement breakers and rock drills cost between $500 and $900 each. Muffled units can cost 5 to 20 percent more and yield 8 to 12 dB lower sound levels. Pile drivers can cost $18,000 to $180,000 and the mufflers from $3,000 to $9,000 (one manufacturer indicates that a muffler adds 30 percent to the price.) With mufflers, reductions of 30 to 35 dB have been achieved in tests. Equipment manufacturer surveys concentrating on earthmoving equipment have disclosed that a 4 to 8 dB noise reduction can be expected at an added cost of 3 to 5 percent of total equipment costs.[4]

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[1] *"Quiet Construction Equipment," Jack Faucett Associates, EPA Contract 68-01-6775, September 1980.*

[2] *Kamperman, G.W. and Nicholson, M.A., "Noise Control Methodology for Army Construction and Materials Handling Equipment," Kamperman Associates, Inc., Contract No. DAAK02-74-C-0231, March 1975.*

[3] *Bach, D. and Meyer I., "Noise Data and Related Data Associated with Paving Breakers, Rock Drills, and Pile Drivers," Informatics, Inc., Rockville, Md., 1974.*

[4] *Schomer, P.D., Kessler, F.M., Chanaud, R.C., Homans, B.L., and McBryan, J.C. "Cost Effectiveness of Alternative Noise Reduction Methods for Construction of Family Housing," Construction Engineering Research Laboratory, Interim Report N-3, July 1976.*

An EPA contractor has estimated that a 20-year program of innovation to produce an average reduction of noise level of 18 dB beyond that available with the best current state-of-the-art will require a 3.2 percent average annual increase in the list price of each item of equipment.[1]

The same study also reports that an average noise reduction of 3.5 decibels can be obtained over a period of 4 1/2 years by retrofitting existing equipment at an average cost of 1.2 percent of the list price of the affected equipment. Exhibits III-1 and III-2, reproduced from that study, show the average cost (in 1972 dollars) per decibel per year for each type of equipment for the innovation and the retrofit programs, respectively, if these relationships are valid.

D. QUIETER OPERATIONS

The opportunities to use equipment in a quieter fashion fall into four classes: (1) operation with all noise reducing equipment and materials that were furnished by the manufacturer in place and in good repair, (2) operation at locations on the site and in ways that reduce the noise levels at sensitive receivers, (3) alternate construction methods, and (4) scheduling the operation of noisier equipment at the same time or at different times of the day, days of the week, or different seasons to match ambient noise levels. These are all discretionary noise reduction options open to the contractor.

The use of all noise control equipment is sometimes not followed by operators who fear that the equipment will overheat, will be less powerful, or will be less fuel efficient. Contractors frequently believe that greater fuel economies are obtained when mufflers are removed from construction equipment. In our discussions we found that more than two-thirds of the contractors believed it. The true facts of this situation need to be established and communicated clearly to the contractors by the manufacturers and their representatives. In other cases, the equipment is misused, poorly maintained, or carelessly serviced. Enforcement by the contractor's site manager and local officials, and sometimes suggestions by equipment manufacturer representatives are needed to correct this source of noise.

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[1] *"Cost Information for Alternative Noise Controls of Various Construction Equipments," Innovative Systems Research, Inc., 1979.*

Equipment	Average Unit List Prices	Annual Expenditure Per Equipment Required Per dB of Noise Reduction
Air compressor	$ 8,500	$ 15.30
Backhoe	18,000	32.40
Concrete mixer	25,000	45.00
Concrete vibrator	2,000	3.60
Crane, derrick	110,000	198.00
Crane, mobile	50,000	90.00
Crawler tractor less than 200 HP	27,300	49.14
Crawler tractor greater than 200 HP	90,000	162.00
Dozer	28,000	50.40
Generator	1,000	1.80
Grader	22,000	39.60
Paver	42,000	75.60
Paving breaker	800	1.44
Pile driver	33,000	59.40
Pneumatic tool	300	0.54
Pump	430	0.77
Rock Drill	35,000	63.00
Roller	11,000	19.80
Saw	100	0.18
Scraper	70,000	126.00
Shovel	71,000	127.80
Truck	18,000	32.40
Wheel loader less than 250 HP	29,000	52.20
Wheel loader greater than 250 HP	80,000	144.00
Wheel tractor less than 200 HP	27,300	49.14
Wheel tractor greater than 200 HP	90,000	162.00
Total	$889,730	$1,601.51
Average	$ 34,220	$ 61.60

Source: *"Cost Information for Alternative Noise Controls of Various Construction Equipment," Innovative Systems Research Inc., U. S. EPA Contract 68-01-4920, January 1979.*

EXHIBIT III-1: ANNUAL EXPENDITURES FOR INNOVATION PER EQUIPMENT PER dB OF NOISE REDUCTION FROM THE INNOVATION (20 YEARS INNOVATION CYCLE) (1972 DOLLARS)

Equipment	Average Unit List Prices	Annual List Price Increases Per Equipment Per dB Noise Reduction
Air compressor	$ 8,500	$ 28.90
Backhoe	18,000	61.20
Concrete mixer	25,000	85.00
Concrete vibrator	2,000	6.80
Crane, derrick	110,000	374.00
Crane, mobile	50,000	170.00
Crawler tractor less than 200 HP	27,300	92.82
Crawler tractor greater than 200 HP	90,000	306.00
Dozer	28,000	95.20
Generator	1,000	3.40
Grader	22,000	74.80
Paver	42,000	142.80
Paving breaker	800	2.72
Pile driver	33,000	112.20
Pneumatic tool	300	1.02
Pump	430	1.46
Rock Drill	35,000	119.00
Roller	11,000	37.40
Saw	100	0.34
Scraper	70,000	238.00
Shovel	71,000	241.40
Truck	18,000	61.20
Wheel loader less than 250 HP	29,000	98.60
Wheel loader greater than 250 HP	80,000	272.00
Wheel tractor less than 200 HP	27,300	92.82
Wheel tractor greater than 200 HP	90,000	306.00
T o t a l	$889,730	$3,025.08
A v e r a g e	$ 34,220	$ 116.35

Source: *"Cost Information for Alternative Noise Controls of Various Construction Equipment," Innovative Systems Research Inc., U. S. EPA Contract 68-01-4920, January 1979.*

EXHIBIT III-2: EQUIPMENT LIST PRICE INCREASES PER EQUIPMENT PER dB NOISE REDUCTION FOR RETROFITTING (1972 DOLLARS)

The location and way of operating the equipment is a difficult issue, because sometimes the contractor has limited freedom of selection without interfering with productivity. When he has this freedom, he may be too preoccupied to use it and will claim he doesn't have it. Building site inspectors are frequently the best judges of this behavior.

Alternate construction methods are frequently overlooked as possible noise reduction options. For example, instead of driving piles for a foundation, sometimes trenches can be dug and filled with concrete. These alternate methods are not always technically applicable, however, and may be quite expensive relative to the noisier method. Nevertheless, alternative methods should not be overlooked.

Scheduling construction activities can also result in quieter operations or reduce the duration of the noise. If noisy equipment is operated during those times of day or days of the week when ambient noise levels are also high, the ambient noise can effectively be used to mask noise from the site. Seasonal scheduling can avoid operating noisy equipment during the spring and autumn months, the so-called "open window seasons." Since noise levels at a receiver do not increase linearly during multiple operation of equally noisy sources, scheduling multiple operations to occur at the same time or construction stage can reduce the noise duration time. In order to conduct especially noisy operations concurrently, contractors should schedule and control their individual subcontractors carefully.

E. SHIELDING AND ENCLOSURES

Fences around building sites are usually constructed to keep people out of the site, but these barriers can be so constructed and placed as to function as effective noise shields or barriers. Pieces of equipment, wood, and removed (or moved) earth can be put to use to form a noise shield. Tractor trailer vans used for materials storage can be placed to shield receivers from noise sources. Earth berms can be constructed from dirt excavated in the construction of building foundations. Shields constructed from wood which are both readily movable and reusable are most common.

Noise barriers can be quite effective where (1) the noise source is at or below ground level, (2) the barrier is high, (3) the noise source is located close to the barrier, (4) the receiver is at or below ground level, (5) the receiver is located close to the barrier, and (6) the frequency of the sound is high. However, if the receivers are located in

multistory structures, for example, the noise shield is ineffective. The applicability of constructing a noise shield will also depend on materials cost, the availability of land on which to construct the shield, and on the degree of site access which is needed.

Alternatively, noisy equipment can be enclosed in specially designed noise enclosures or "sound baffle houses." This approach is really only viable for stationary or semi-stationary equipment from which good visibility is not needed. These enclosures can be moved to and reused at different sites. Enclosures are effective in reducing noise if properly maintained and can be applied to advantage in situations in which shields or barriers would be ineffective because they would not interrupt the direct sound path between the source and the receiver.

F. NOISE PREDICTION METHODS

In cases of very large construction and engineering projects such as airfields, electric power plants, and bridges, it may be possible and valuable to build a mathematical model of construction site noise levels as a function of time. Various models are available. Hongo[1] has developed a noise level prediction model requiring as inputs (a) dimensions of the border of the site, (b) the number and kinds of machines to be used, (c) kind and duration of the work, (d) noise level of each machine at a specific distance, (e) geometry of buildings around the site, (f) area of calculation, and (g) other data necessary to draw noise level countours. Essentially models can be built to match the complexity desired.

Schomer[2] developed a model which satisfactorily predicted noise levels from some residential construction, but he warns that the model was not validated for other situations with different usage factors. Even so, the model provides useful insight for other investigators and to planners who wish to predict the effectiveness of noise control measures in reducing the sound levels in the community surrounding the construction site.

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[1] *Shing-ichi Hongo, "A Method for the Prediction of Noise Levels at Construction Site Boundaries," Earthmoving Industry Conference, Society of Automotive Engineers, Peoria, Ill., 1978.*

[2] *Schomer et al, op cit.*

IV. EFFECTIVE LOCAL PROGRAMS

A. ZONING AND LAND USE PLANNING

A local government is unlikely to undertake a noise program if it lacks any zoning or land use planning program. These are the most effective forms of community noise control and apply to construction noise in addition to their more obvious application to transportation and industrial noise. Zoning and land use restrictions partially insure that residential areas will not be exposed to severe construction noise problems. Although residential construction noise and noise from street improvements, sewers, and conduits all are annoying, they are not like commercial projects because they do not require deep excavations, driving of piles, or many months of construction in the same place.

B. PROVISIONS FOR CONSTRUCTION NOISE IN LOCAL ORDINANCES

A local community is unlikely to undertake a noise control program for construction noise unless it also is addressing other sources of noise. The following construction noise provisions are good samples for inclusion in any local noise control law.

1. Curfews. A violation consists of:

> "Operating or permitting the operation of any tools or equipment used in construction, drilling, or demolition work: between the hours of _____ p.m., and ___ a.m. the following day on weekdays or at any time on (Sundays/weekends) or holidays, such that the sound therefrom creates a noise disturbance across a residential real property boundary or within a noise sensitive zone, except for emergency work of public service utilities or by special variance...."[1]

Curfews are most widely used. They are effective, easily understood, and the most enforced of all noise provisions relating to construction.

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[1] *"Model Community Noise Control Ordinance," National Institute of Municipal Law Officers, U.S. EPA 550/9-76-003, September 1975.*

2. Noise control equipment.

> "It shall be a violation to operate any piece of construction equipment without all of the noise reducing and noise control equipment furnished by the manufacturer, in place, in use, and in good repair."

This means that mufflers must be working, access doors for air compressors must be closed, enclosures and jackets must be in place, fiberglass acoustical blankets must be installed, and shock and vibration mounts must be intact. It is a reasonable requirement, fairly easy to enforce by inspection.

3. Property line or receiving property noise level limits. A violation consists of:

> "Operating or permitting the operation of any tools or equipment used in construction, drilling, or demolition work (at any time other than the specified curfew hours) such that the sound level at or across a real property boundary exceeds an $L_{eq(1)}$ of _____ dBA. For any source of sound which emits a pure tone or impulsive sound, the maximum sound level limit shall be reduced by ____ dBA."[1] The term $L_{eq(1)}$ is the symbol for the energy average sound level over one hour.

4. Applicability to local government equipment. The purpose of this provision is to single out municipal equipment and its operators as subject to the same provisions as the rest of the population and to make the municipality act as a good example. This noise ordinance provision may state that, "All provisions of this ordinance shall apply to all municipally owned or operated equipment except as exempted while engaged in emergency repair work."

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[1] *"Model Community Noise Control Ordinance," National Institute of Municipal Law Officers, U.S. EPA 550/9-76-003, September 1975.*

5. Exemption for emergency repair work. This provision provides an exemption from noise control ordinance regulations for all emergency repair work. Emergency work frequently is defined as: "any work performed for the purpose of preventing or alleviating the physical trauma or property damage threatened or caused by an emergency." Emergency is taken to mean "any occurrence or set of circumstances involving actual or imminent physical trauma or property damage which demands immediate action."[1]

6. Backing signals. Noise control ordinances can include a provision that "backing signals (i.e., a beeping or ringing tone indicating that a vehicle is backing up) shall not be audible at locations at which the construction noise is not audible." These backing signals frequently are highly annoying; the provision limits the level of backing signals to approximately that of the construction noise. Thus the backing signals will protect workers by being audible at any place that the backing piece of equipment might go, but not audible in places off the construction site at which the construction noise is also not audible.

7. Contractual construction noise specifications. Municipalities, counties, and States can elect to place construction noise specifications in their construction contracts instead of or in addition to promulgating a separate noise control ordinance. Contractors agreeing to the specifications then are legally bound to comply or face penalties or termination of the contract. Examples of possible construction contract specifications are shown below.[2]

   A. The contractor shall perform all work within the permissible noise levels, day of week, and hour of day limitations, and within the procedures provided for in all applicable Federal, State, and municipal codes, regulations, laws, and standards.

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[1] *"Model Community Noise Control Ordinance," National Institute of Municipal Law Officers, U.S. EPA 550/9-76-003, September 1975.*

[2] *Riggins, R.E. et al., "Environmental Protection Guidelines for Construction Contract Specification Writers," U.S. Army Corps of Engineers, Construction Engineering Research Laboratory, April 1975.*

B. The contractor shall be responsible for and shall obtain at his own expense equipment registrations, operating certificates, tunneling permits, and any other document required by all applicable State and municipal codes, regulations, and laws.

C. Without in any way diminishing his obligation to fully comply with applicable Federal, State, and municipal codes, regulations, laws, and standards, the contractor shall perform the work in accordance with any or a combination of the following stipulations inserted into the contract by the contract drafter: (1) and/or (2) and/or (3a) or (3b) and/or (4).

D. The contractor shall idemnify and save harmless [the U.S. Army Corps of Engineers] from and against any and all liability, to state or local governments or to other third parties, which may result from failure to comply with the codes, laws, and other requirements referred to herein and shall reimburse the [U.S. Army Corps of Engineers] for all costs incurred in connection therewith, including without limitation, legal expenses and payment of fines.

(1) The contractor will use methods and devices as listed below, that accomplish the attenuation of noise in individual pieces of machinery.

(a) Mufflers that provide a dynamic insertion loss of 20 dB(C) shall be installed on internal-combustion engine exhausts.

(b) Pneumatic tools and devices, including receiver tank vents, shall be equipped with air-exhaust mufflers.

(c) When saws are required, electric-powered chain saws or circular saws shall be utilized. Saws powered by internal combustion engines may not be used in the performance of this contract.

(d) When steel decking or plates are required in performance of the contract, they shall be securely installed to avoid unnecessary rattling.

(2) Certification of individual construction machines will be accomplished according to a prescribed manner...

(3a) Measurement of noise that crosses the boundary of a construction site will be made at various stations beyond the boundary (the nearest property line that delineates inhabitated property or noise-sensitive farm operations and is not under control of the contractor), but, in any case, at a distance of no nearer than 15 m to a predominant work area.

The representative sound level ____ will be obtained in accordance with SAE recommended procedures and will not exceed those values of ____ listed in....

(3b) Measurement of a construction site noise shall be evaluated at the nearest noise-sensitive area in accordance with SAE procedures. (Table ___) provides values of sound levels that are not to be exceeded for the three classes of land-use areas that correspond to the different phases of construction.

(4) Nighttime (2200-0700 hr) sound levels values for Class 1 residential areas are never to exceed 45 dB except in an emergency.

Exhibits IV-1 and IV-2 present state and local community survey data on the types and features of construction noise provisons enacted in these jurisdictions. The surveys show that property line or receiving property noise level limits and curfews are popular construction site noise control provisions. Some communities also set source-distance limits (i.e., cannot exceed x dBA at a distance of 50 feet) for construction equipment.

(Text continues on page 28)

State	Number Of Jurisdictions Having A Noise Ordinance		Noise Ordinance Provisions-Construction			
			Quantitative		Non-Quantitative	
	1976	1980	1976	1980	1976	1980
AL	6	8	0	1	1	1
AK	3	3	0	0	0	0
AZ	5	5	0	2	0	1
AR	2	3	0	0	0	0
CA	116	127	16	23	19	21
CO	12	14	3	1	0	0
CT	7	21	1	3	0	0
DE	1	2	0	0	0	0
DC	1	1	0	9	0	0
FL	69	134	3	21	5	4
GA	29	32	2	3	2	4
HI	1	1	0	0	0	0
ID	3	3	0	0	0	1
IL	16	367	3	367	1	0
IN	8	15	0	0	2	1
IA	10	14	0	0	4	2
KS	3	3	1	1	0	0
KY	4	6	1	2	1	1
LA	2	6	0	2	1	2
ME	-	2	-	0	-	0
MD	3	6	0	0	0	0
MA	9	18	0	1	1	2
MI	21	39	2	5	1	2
MN	8	15	1	4	1	1
MO	8	53	2	4	1	2
MS	1	1	0	0	0	0
MT	5	5	1	3	0	0
NE	6	7	0	0	2	0
NH	3	4	0	1	0	0
NJ	67	72	1	2	4	6
NM	3	4	0	1	1	2
NY	42	48	0	2	3	7
NV	1	2	0	0	0	1
NC	55	58	0	1	3	9
ND	2	2	0	0	0	0
OH	12	23	1	1	1	2
OK	2	6	0	0	0	1
OR	23	30	1	1	2	4
PA	12	25	0	1	0	1
RI	5	5	1	1	0	0
SC	2	3	0	0	0	1
SD	2	4	0	0	0	0

(continued)

EXHIBIT IV-1: QUANTITATIVE PROVISIONS IN LOCAL CONSTRUCTION NOISE REGULATIONS

State	Number Of Jurisdictions Having A Noise Ordinance		Noise Ordinance Provisions-Construction			
			Quantitative		Non-Quantitative	
	1976	1980	1976	1980	1976	1980
TN	5	7	0	1	3	3
TX	17	22	0	0	6	9
UT	5	7	3	4	0	0
VT	-	0	-	-	-	-
VA	10	12	0	1	2	2
WA	15	24	1	1	4	3
WA	15	24	1	1	4	3
WV	-	2	-	1	-	0
WI	5	10	0	3	0	1
WY	6	6	0	0	0	0
TOTALS	653	1290	45	465	71	98

	1971 Values	1976 Values	1980 Values	Ratio 1980-1976
Number having a Noise Ordinance	NA	653	1290	1.98
Number and Percent Applying to Construction	15 NA	116 18%	563 44%	4.86
Number and Percent Applying to Construction Having Quantitative Provisions	5 33%	45 39%	465 83%	10.47

NA = not available

Source: *"Construction Noise Control Technology Initiatives," ORI, Inc., Technical Report 1789, September 1980.*

EXHIBIT IV-1: QUANTITATIVE PROVISIONS IN LOCAL CONSTRUCTION NOISE REGULATIONS

(continued)

MACHINE NOISE

(dBA levels at 50 feet unless noted otherwise)

Description \ City	Chicago	Boston	N.Y. City
Sale or lease of new construction and industrial equipment	After 1/1/72 94 After 1/1/73 88 After 1/1/75 86 After 1/1/80 80	After 1/1/72 94 After 1/1/73 88 After 1/1/80 80	
Air compressors (operate or permit to be operated) at 1 meter			12/31/72 90 6/30/74 80
Air compressors (sell, offer for sale, permit to be operated) at 1 meter			12/31/72 85 6/ 30/74 75 12/31/75 70
Agricultural tractors and equipment	After 1/1/72 88 After 1/1/75 86 After 1/1/80 80	After 1/1/72 88 After 1/1/75 86 After 1/1/80 80	
Powered commercial equipment intended for infrequent use in residential area (chain saws, pavement breakers, log chippers, etc.)	After 1/1/72 88 After 1/1/73 84 After 1/1/80 80	After 1/1/72 88 After 1/1/73 84 After 1/1/80 80	
Powered equipment intended for repetitive use in residential area (lawn mower, garden tools, etc.)	After 1/1/72 74 After 1/1/75 70 After 1/1/78 65	After 1/1/72 74 After 1/1/75 70 After 1/1/78 65	
Motor vehicle claxons at 25 ft 1974 models and thereafter			75
Emergency signal devices at 50 ft			90
Paving breaker at 1 meter			12/31/73 94 12/31/75 90

EXHIBIT IV-2: TYPICAL LOCAL NOISE LEVEL LIMITS

OTHER OBJECTIVE STANDARDS

City	Description
Aspen, Colorado Boulder, Colorado	Specifies a limit of 80 dB(A) @ 25 ft from noise source or at least 25 ft from the property line on which the noise source is located.
Medina, Washington	Any level greater than 95 dB(A) @ 20 feet from noise source.
Indianapolis, Indiana	Speakers and sound amplifying equipment <115 dB @ 6 inches from speaker.
Salt Lake City, Utah	Drive-in restaurants: Octave Band — dB (re 0.002 dynes/cm^2) 600-1200 — 50 1200-2400 — 44 2400-4800 — 37
Palo Alto, California	Includes 83 dBA limit from individual construction equipment at 25 ft; 86 dBA limit at any point outside of the property plane of a construction project.
San Francisco, California	Includes limits on waste disposal services, garbage collection, etc., 80 dBA at 50 ft on and after 6 months after effective date reduced to 75 dBA on and after 66 months after effective date. Includes limits on motor vehicles for off-highway use.
Park Ridge, Illinois	Establishes aircraft runway extensions defined as areas 1200 feet wide and five miles long which adjoin existing runways at O'Hare International Airport, the center line of the runway continuing as the center line of the extension. Noise above 95 dBC measured within this area is prohibited.
Santa Barbara, California	Restricts all nonflight activities of aircraft to the community noise equivalent level (CNEL) of 80 dBA.
Portland, Oregon	Heliports are prohibited in residential and commercial zones if the noise from these facilities at landing or takeoff exceeds 90 dB at the boundary of adjacent property in residential areas, or at the nearest occupied premises in commercial zones.

Source: *Construction Engineering Research Laboratory, "Construction Noise - Specification, Control, Measurement, and Mitigation," April 1975.*

EXHIBIT IV-2: TYPICAL LOCAL NOISE LEVEL LIMITS (continued)

C. ENFORCEMENT

Inclusion of provisions for construction noise in local ordinances will be useful and effective only if the means and the motivation for effective enforcement exist as well. Successful enforcement of noise laws is a combination of coercion and cajolery. The enforcing officer always has other duties, almost always with a higher priority than construction noise abatement. He must balance between responding to complaints and helping contractors to stop making noise by finishing quickly. The provisions for enforcement that follow have been chosen from many people's experience with many alternatives. They provide a balance between prevention and correction, between avoiding and solving problems, and between giving orders and offering advice.

1. Authority should be clearly understood. It is recommended that the Building Department should normally be responsible for the enforcement of the construction noise portion of the ordinance. If this is not desirable for some reason, the next choices are the health department and the environmental department or the police department. In any case it is suggested that the police department should be used to enforce the curfew provisions when the department having primary enforcement responsibility is not on duty. The police should refer other complaints to the primary authority and should support the primary authority when necessary. This may include accompanying the building inspector on visits to construction sites.

2. A complaint center is very important. It is recommended that every noise control program should include a complaint center, the telephone number of which is well known to the public. The center should be familiar with the provisions of the ordinance and should know to whom to refer the caller if the local government is not responsible for investigation of the complaint (outside the jurisdiction), or will not investigate (because the source is emergency work or a variance has been issued.)

3. A Construction Noise Board of Adjustment is valuable. It is recommended that a community have a board, consisting of five citizens, one of whom must be representative of the construction industry, and one of whom must be a professional acoustical engineer, audiologist, or other specially qualified person, which is the only source of variances if the noise levels are expected to be too high to comply with the ordinance and therefore a building permit may not be issued. This group is not expected to be needed often, but when it is, it relieves pressure on the noise control enforcement officials.

4. Preconstruction conferences are helpful. A portion of the enforcement program should consist of regular preconstruction conferences at which the contractors are told about the provisions of the noise control and other environmental laws and the contractor's plan for construction is reviewed so that problems can be anticipated and avoided.

5. Penalties should be anticipated and stated. A plan of warnings, citations, fines, injunctions, closings, and other penalties should be adopted with a schedule for imposition. It should be flexible but well enough understood so that the contractors know what will happen if they violate the ordinance. It should be clear that the actions may be initiated by either the public or the municipality.

D. PUBLIC AWARENESS AND EDUCATION

Construction noise should be included in the awareness campaign that is part of the whole noise control program. The communities that have successful noise control programs spend considerable effort educating the public about the program and the steps each citizen can take to help it. Special additional material is given to school children in classrooms and in assemblies. Information is posted in public places, publicity is given in the press and broadcast media when quiet equipment, quiet periods, or quiet areas are newsworthy. The existence of an environmental center or a noise center that will give information and will produce responses to complaints about noise is given wide publicity and recognition. The public should know that the complaint center acts on construction noise complaints, too. Notice of the curfew hours should be widespread. Citizens should be shown how to spot missing or improperly used noise control equipment on construction equipment.

E. BUY-QUIET PROGRAMS

A Buy-Quiet Program should be included in every community's noise control program. Health, building, and/or environmental officials should work closely with purchasing agents to get such a plan started, and Buy-Quiet specifications should be written into municipal, county, or State purchasing agreements.

The Buy-Quiet Program is a non-regulatory, market approach to noise control. Its aim is to induce industry to develop and market quieter products by organizing a "market

for quiet." The initial thrust of the program is to leverage the $300 billion public sector market by organizing government purchasing cooperatives and by working through professional purchasing organizations. The program then extends this process to the private sector.

The program works through use of noise reduction incentives (rather than compulsion) and relies upon cooperative (rather than adversary) communication links with industry.

The program was begun by EPA, and participants in the program now include Government Services Administration, the National Institute of Governmental Purchasing, the National League of Cities, and local, State, and Federal purchasing agencies and cooperatives.

The program is in four parts:

A Quieter Products Program involves a series of governmental/industry conferences to develop quiet product purchase descriptions which cities and other governments use.

Local Buy-Quiet Programs, in which purchasing cooperatives and individual governments agree to "buy quiet" as an ongoing activity, form the core of the program and are targeted for special assistance.

Data Bank for Quiet Purchasing, operated by the National Institute of Governmental Purchasing, helps purchasing agents and others in buying quiet products.

Quiet Product Demonstrations in which quiet products that are loaned to local governments serve to demonstrate what can be achieved with the "buy quiet" concept.

Industry is in this fashion provided with an organized market for quieter products. Special noise reduction incentives are included in procurement requests. Procurement specifications normally require that products purchased meet minimum performance standards. Those that do, then compete on the basis of price so that the sale goes to the least expensive product which meets minimum product specifications. Under the Buy-Quiet Program, bids are evaluated on the basis of both noise level and price, with a

dollar for decibel trade-off being specified in the request for bid. Suppliers thus compete with one another for the sale on the basis of both noise level and price. This creates a market force which operates to provide quieter products at competitive prices.

Buy-Quiet Programs can provide an excellent vehicle for beginning the process of organizing and planning a local noise program. Buy-Quiet now is promoted throughout EPA's public information and technical assistance channels as well as through the purchasing officers network coordinated by the National Institute of Governmental Purchasing (NIGP). For example, by working closely with the 40 governments of the North Central Texas Council of Governments who are organizing a cooperative Buy-Quiet Program, the EPA's technical assistance effort has created a vehicle for promoting active noise programs in a large number of communities.

In addition, certain governments that already have active noise control programs consider Buy Quiet as an important complement to their existing noise control ordinances. For example, almost one third (20) of the 64 governments which have either committed themselves to a Buy-Quiet Program or who are now considering a Buy-Quiet Program are governments having active noise programs.

Because it works in harmony with national market forces and uses cooperative rather than compulsory mechanisms, the Buy-Quiet process has the potential for being dramatically more cost effective than many alternative controls. By leveraging the market, it unleashes the normal competitive instincts of private industry to produce quieter products rather than directing these instincts to protect industry against regulations. Further, for the expense of operating this program there is virtually no limit to the number of products that can be covered. However, providing product noise emission information does increase annual costs for equipment manufacturer's since these products must be tested.

F. INVOLVEMENT OF CITIZENS AND CITIZENS' GROUPS

In many communities and in some States the initial pressure for a noise control program began with citizens' protests against excessive noise, usually from aircraft or highway traffic. The objections and suggestions of such groups have been the chief reason why many takeoff and landing procedures have been modified and many thousands of feet of

highway noise barriers have been constructed. If such a group is in existence, its assistance may be used to encourage contractors and local or State officials to devote extra attention to the problems of construction noise.

If there is no such organization, there may be neighborhood advisory boards, wards, councils, or local environmental conservation groups who will help the local government and local citizens in starting and maintaining a noise control program with a construction noise part. Resources such as societies of professional engineers, societies for hearing measurement and conservation, local science educators, noise control and acoustical consultants, and trade associations all are possible sources of interested and skilled participants in a noise control program.

When the State of Iowa was preparing a noise control strategy, it formed a technical advisory committee with members selected from the engineering, hearing, and audiology departments of universities, noise control consultants, and professionals in other related fields throughout the State. Portland, Oregon, has a Construction Noise Committee that acts much like a zoning board of adjustment, for only it can grant variances to the noise ordinance when building permits are issued. Of the five members of the committee, one must be a representative of the construction industry and one must be a professional in the field of noise. In several communities a member of the American Association of Retired persons has been trained in noise control techniques and now serves either as an assistant to local noise control officials or as a neighborhood communications channel in noise control matters.

V. COSTS OF EFFECTIVE LOCAL PROGRAMS

Because we believe that construction noise programs will be adopted only by communities that have or will have programs for controlling noise from other sources as well, the costs are calculated on a differential basis, the marginal cost of adding construction equipment to a program. Alternatively these costs may be regarded as an allocation of the total costs of the program to the construction portion.

The personnel requirements of a construction noise program such as that described in Section IV for a city of 100,000 is estimated to be about 4 hours per week. This is sufficient time to investigate two or three complaints per week, one of which may require taking a sound level measurement. It also is sufficient to attend a preconstruction contractors' meeting every other week and to meet with contractors and answer telephone calls specifically about construction noise. The noise control officer may advise the municipal purchasing agent concerning purchases under the Buy-Quiet Program and may review plans for major construction projects or for municipal construction. Some of these activities will be needed only monthly or even more infrequently.

The use of a clerk-typist 4 hours per week should be adequate. The equipment requirements are a sound level meter, a hand calculator, and the use of a municipal vehicle for use in investigating complaints.

Current estimates of average costs of a municipal building or environmental officer including allocation of overhead and pension are $23,000 to $30,000 per year. The cost of a clerk-typist is $11,000 to $14,000 on the same basis. The cost of a type 2 sound level meter is estimated at $800 initial cost with a useful life of 8 years and an annual cost of $50 for calibration, repairs, and batteries. The cost of a municipal car is estimated at $3,500 per year.

Therefore the total estimated costs are:

10% of noise control official	@ $26,500	$2,650
10% of clerk	@ $12,500	$1,250
sound level meter depreciation and maintenance		$ 150
10% of municipal car	@ $ 3,500	$ 350
Total		$4,400

EPA recently sponsored a study[1] of the desirable number of people on the noise control programs of local governments for populations ranging from 20,000 to 3,000,000. Few communities seem likely to achieve the levels of professional and nonprofessional manpower this report recommends, but the scaling factors in the report seem quite reasonable. For local governments with populations greater than 100,000 people the report suggests an additional one-half professional person for each additional 100,000 people. Thus, if a city of 100,000 people has one full-time professional person devoted to all aspects of noise control, a city of 300,000 nominally would have two full-time professionals.

Therefore, the total costs can be estimated for the addition of a construction noise portion to an existing noise control program. If the locality has a population greater than 100,000, the estimated cost will be given by the equation: $4,400 [(population + 100,000)/200,000] in 1981 dollars.

For a city of 100,000 this amounts to 4.4¢ per resident per year. A survey by the National League of Cities of cities that have noise control programs showed that small cities (less than 50,000 with an average size of 32,000) spent 32¢ per resident per year on the whole noise control program (1978 dollars). For large cities (more than 50,000 with an average size of 206,000) the corresponding amount was 14¢.

It is very hard to evaluate the effectiveness of a community program to reduce construction noise. Construction sites and activities vary so widely that there seldom are comparable situations for which sound level measurements before and after the program could be compared.

Enforcement is almost entirely in response to complaints, so continuous or sample monitoring by the enforcing officers is not practical. Counting the complaints is a poor way to evaluate effectiveness, because the number of complaints frequently is more an index of how widely people know about the existence of the office that receives the complaints and how much good they believe a complaint does than an indicator of the number of noise violations or annoying incidents. If a complaint center is established and is effective, usually the number of complaints rises, at least initially.

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[1] *"Task Analyses of Manpower Sampling for the Development of Program Models," E.H. White and Company, Inc., 1979.*

Therefore, we suggest the use of the number of multiple or repeat complaints about noise from the same source as a measure of effectiveness of a local noise control program for construction noise. In many communities a single individual may receive and act on all construction noise complaints. In such cases it is easy to keep track of the number of complaints that are received about a particular source and the number of these that were received after the officer investigated and reported the results to the complainant and to the contractor, if necessary. In the case of larger communities, the staff that does noise control work may have to compare entries in the complaint log to count the number of repeat or multiple complaints about a particular source.

We know of no communities that keep and report such statistics, so we cannot predict the level of success that a given level of activity is likely to produce, but we find that many noise control officers think in terms of repeat curfew violations by a contractor, continued failure to muffle a piece of equipment, or multiple warnings to a utility for its street opening crews to use silencers on the pavement breakers. Because the officers think in these terms, it is reasonable to expect that the number of repeat complaints is a useful index of noise control performance.

VI. CONCLUSIONS

The construction industry is unique. No other industry has the same combination of labor, capital, laws, management, technical resources, and traditions. Construction takes place all over the United States in rural, suburban, and urban areas every day of the year, so noise reduction in this industry is a national problem. Fortunately the techniques for the reduction of construction noise also apply all of over the country, even though they may apply for only a short time in a particular location.

The outstanding difference between construction and other industries is that construction is, by definition, a temporary activity. There are very few construction projects that last several years. Even very large buildings and roads are under construction in a particular area for only a reasonably short time, seldom more than two years. The noise from such a project changes as the different phases of the construction are completed. Noise control programs that take a long time to mature or officials that are very slow to act usually find that the problem is gone by the time they are effective. A construction contractor often can avoid many complaints by explaining to affected residents how soon the construction will be finished and how great its benefits will be to the neighborhood.

Construction noise is a site-specific problem. There are many factors which contribute to construction noise, including the type or phase of construction, the combination of equipment used, the site layout, and the techniques being used.

There is no blanket prescription for controlling construction noise and the exposure to the noise. Similar types of construction activity can have different exposure impacts, depending on the location of the construction and the population surrounding the site.

The uniqueness of each construction site calls for a combination of control measures centered around those measures which can be directed specifically to the type of site and the resultant exposure. For the most part, this is best done at the local level, where all factors can be considered, ordinances can be enforced, and, if necessary, penalities can be levied. The primary thrust of construction noise control, therefore, must revolve around in-use controls. A few other types of noise controls can be used to supplement in-use controls. One control is the purchase of quieter equipment, and the Buy-Quiet Program is a promising, entirely voluntary movement in that direction.

Many manufacturers stated that noise supressed product lines were, or soon would be, available. The literature is full of articles on quieter equipment. However, even if all new equipment used were the quietest available, there would still be a construction noise problem. Some contributing factors are the potential for deterioration of equipment in the field if it is not properly maintained and the necessity for combined operation of new, quieted equipment along with older, noisy equipment.

In-use controls can address most construction site noise problems effectively. Such controls include hours of operation, operation of equipment with its noise control equipment, location of the equipment on the site, use of alternate equipment, rerouting vehicles, property-line standards, and operator concern.

In-use controls have many advantages. They can be effective immediately after a local ordinance is passed. They are effective against older, noisy equipment; moreover, they may be necessary in the case where the noise from a quieter piece of equipment is overshadowed when used in conjunction with another piece of equipment with an equal or higher noise level.

Adverse effects from noise are caused not only by the level of noise, but also by the time of day or night in which the noise is made. For example, a noisy operation in a commercial area is best done after regular working hours, when most workers are at home. Conversely, a noisy operation in a residential area is best performed during the day, when most people are not sleeping and many are not at home. Although the overall level of noise from the site may not be mitigated, exposure to the noise can be greatly reduced.

Large reductions in noise levels (and exposure) can be achieved by the operation of construction equipment with all its proper noise control equipment in place and in good repair. For example, just correcting a defective muffler can reduce the noise by 10 dB.

Operator concern can greatly affect the way equipment is used and maintained. This has to be done through information dissemination and training. A side benefit is the possible fuel conservation which may occur through proper use and maintenance of equipment. For example, chances are that a truck in good repair with a proper exhaust system and a temperature-actuated fan will be more efficient than a truck with improper back pressure resulting from a defective exhaust system and a direct-drive fan.

These types of in-use controls apply to all types of equipment — whatever the combination. Unlike most new product regulations, they are not dependent on technological (and cost) considerations.

Locally imposed in-use controls usually cost less than other controls. It is cheaper to repair a defective exhaust than to modify the whole cooling system to meet Federal regulations. In fact, communities can use incentives to encourage construction noise abatement. Such incentives include higher building permit fees, more documentation if noisy equipment is to be used, and preconstruction conferences.

The cost of an effective local program, including enforcement of ordinances, is also low. Because it is likely that construction noise programs will be adopted only by communities that have or will have programs for controlling noise from other sources, the costs can be calculated on a differential basis, where only the marginal cost of construction noise control is considered.

In summary, quieter equipment will help the construction noise problem, and manufacturers should be encouraged to provide the quietest equipment possible. However, the availability of some quiet equipment will not solve construction site noise. In-use controls are a necessary element. They are most effective when implemented and enforced at the local level where they can be tailored to a specific community need. Where there is already a noise control program, the addition of a construction noise component is minimal. Even a new program would yield noise exposure reduction well worth the cost.

States and localities should act now in order to promote an environment free of noise that jeopardizes people's health and welfare.

APPENDIX

ORGANIZATIONS THAT WERE CONTACTED DURING THE PREPARATION OF THIS REPORT

State and Local Governments

California
Kentucky
Gainesville, FL
Norfolk, VA
St. Paul, MN
Boulder, CO
Alexandria, VA
New Orleans, LA
Raleigh, NC
Perth Amboy, NJ
Toledo, OH
Salt Lake City, UT
Des Moines, IA
Connecticut
New Jersey
Boston, MA
Council Bluffs, IA
Philadelphia, PA
Arlington, VA
San Diego, CA
Miami, FL
Charlotte, NC
Bloomington, MN
New Brighton, MN
Clayton, MO
Brookline, MA
Illinois
Oregon
National City, CA
Los Angeles, CA
Bradenton, FL
Seattle, WA
Scottsdale, AZ
Albuquerque, NJ
Columbus, OH
Portland, OR
Colorado Springs, CO
Garland, TX

Equipment Manufacturers

Allis-Chalmers
J. I. Case
Caterpillar Tractor Co.
Clark Equipment Co.
Deere & Company
Digmor Equipment & Engineering Co.
Massey Ferguson Ltd.
Blaw-Knox Construction Equip. Co.
Gallion Manufacturing Div.
Crane Division Inc.
Bucyrus-Erie Co.
Marion Power Shovel Co.
White Motor Corporation (Construction Equipment Division)
Foundation Equipment Corp.
Commaco, Inc.
Ingersoll-Rand Power Tool Div.
Stow Manufaturing Co.
Equipment Development Co.

Trade Associations

Construction Industry Manufacturers Association
American Society for Concrete Construction
Council of American Building Officials
National Construction Industry Council
American Building Contractors Association
National Association of Demolition Contractors
Hydraulic Tool Manufacturers Association
Associated Builders and Contractors, Inc.

Community Organizations

American Association of Retired Persons
National Association of Neighborhoods
National Association of Counties
National League of Cities
National Association of County Health Officials

Labor Unions

AFL-CIO (Building and Construction Branch)
Laborer's Union of North America
United Brotherhood of Carpenters and Joiners of America
International Union of Bricklayers and Allied Craftsman

Contractors

Master Builders
Logan Construction Inc.
Norwood Industrial Construction Co.
Knott Restoration Services
James Vito & Sons Construction Co.
Donohoe Construction Co.
Baldi Construction Engineering Inc.
George Hyman Construction Co.
Ratrie, Robbins, and Schweizer, Inc.
Contee Sand & Gravel Co.
Omni Construction
Montview General Contractors
Hutchison Brothers Excavating Co.
G & C Construction Corp.
Carr-Hill
Centennial Contractors Inc.
Chesapeake Contractors Inc.
Corson & Gruman Co.
DiMaio Brothers Inc.
Eastern Tunneling Corp.
Suburban Utilities Contractors Inc.
Smither Inc.
Saman Construction Co.
Consolidated Building Systems
B & B Excavating
Hendrick Browne & Assoc. Inc.
Bonfils Development Inc.
Equitable Construction Co., Inc.
Rod Brewer General Contractors, Inc.
Edsall Corporation
Excavation Construction Inc.
Gunite Construction Co.
Potts & Collahan Inc.
Pikesville Contracting Corp.
Bates and Associates
East Atlantic Construction Co.
Metropolitan Construction Co.
Bell S J Construction Co.
Button and Goode Inc.
C F & B, Inc.
Dustin Jesse & Son, Inc.
Majestic Builders
Merkli & Lester Inc.
Polinger Construction Co.
Robert Henley Construction
Ferguson Construction Co.
Case Inc.
Century Construction Co. of D.C.
John Clayborne, Inc.
Weygandt Engineering Inc.
White Oak Construction Inc.
Volpe Construction Co.
Three State Construction Co., Inc.
Savoy Construction Co.
Edmund Ault Ltd.
CMS Contractors Inc.
James Galloway Construction Co.